Journal of Risk Research
Vol. 11, No. 3, April 2008, 335–350

Routledge
Taylor & Francis Group

Fishing and consumption patterns of anglers adjacent to the Oak Ridge Reservation, Tennessee: higher income anglers ate more fish and are more at risk

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The risks from consuming self-caught fish are receiving international attention because of high levels of contaminants in some species. The ethnic, income, and educational differences in fishing and fish consumption patterns of 202 anglers fishing along the Clinch River arm of Watts Bar Reservoir adjacent to the US Department of Energy's Oak Ridge Reservation (ORR) or along Poplar Creek within ORR boundaries were analyzed to understand how to design a risk communication strategy. Because of elevated PCB concentrations in striped bass (*Morone saxatilis*), catfish (*Ictalurus* spp.), and sauger (*Stizostedion canadense*) due partly from contaminants released from the ORR in East Tennessee, the Clinch River arm of Watts Bar Reservoir is under a fish consumption advisory, while portions of Poplar Creek are under advisories because of mercury. Most studies find that a high proportion of anglers eat their catch, and people with lower incomes and less education generally eat more self-caught fish than others fishing in the same region. Calculating fish consumption individually for each person indicated that a considerable number of people ate more fish from the study area than the amount used to calculate risks when developing fish consumption advisories, and people who ate fish more often usually ate larger portions. Unlike previous studies of fish consumption, this study indicated that a smaller proportion of anglers ate their fish, and those that ate the most were the high income anglers for this fishing population, rather than those with lower incomes. This suggests that risk communication strategies must include site-specific information on the population at risk from fish consumption, and that targeting only low income, low education anglers will miss some people who are most at risk.

Keywords: fish consumption; individual fish consumption rates; high income consumption; consumption advisories; Oak Ridge Reservation; East Fork Poplar Creek; Clinch River

Introduction

In the southern United States where the fishing season lasts for most of the year, recreational and subsistence fishing are significant features of rural culture and tradition (Toth and Brown 1997; Burger 2002). High fishing rates are not limited to the southern US, but also occur in urban areas (Burger et al. 1999a; Bienenfeld, Golden, and Garland 2003), among Native Americans (Harris and Harper 1998; Burger 1999; Burger et al. 2007), and in other parts of the world. Fish is an excellent, low-fat source of protein and provides many benefits, such as contributing to low

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ISSN 1366-9877 print/ISSN 1466-4461 online

DOI: 10.1080/13669870701795560
http://www.informaworld.com

blood cholesterol (Anderson and Wiener 1995). However, the occurrence of contaminants in fish may be a hazard to human health, especially for high risk groups, such as fetuses, young children, and nursing mothers (Guallar et al. 2002).

The safety of non-commercial fish is important to both the general public and government agencies. The number of acres of lakes under fish consumption advisories in the United States increased from 26% in 2000 to almost 28% in 2001, while the number of river miles under advisory increased from 10.5% in 2000 to 14% in 2001 (USEPA 2002). Overall the number of state fish advisories due to chemicals has increased by 125% since 1993 (USEPA 2004). Mercury, PCBs, chlordane, dioxins, and DDT were at least partly responsible for 96% of all fish consumption advisories. The increase in fish consumption advisories could be due to a real increase in environmental contamination, to increases in the number of assessments conducted, or to the improved quality of monitoring and data collection methods (Burger et al. 2001a, b).

Examining the fishing behavior, fish consumption, and fish cooking patterns of people who fish in waters under advisories is important since anglers may consume large amounts of fish (more than 0.35 kg/day) (Burger, Cooper, and Gochfeld 1992; Burger et al. 1999a, b; Stern 1993). In a study conducted on the Savannah River along the US Department of Energy's Savannah River Site (SRS) in South Carolina, which is under a fish consumption advisory due to elevated mercury and radionuclide concentrations, anglers ate an average of 1.46 kg fish/month; however, some people ate up to 9.55 kg fish/month (Burger et al. 1999b). Site-specific information is necessary to implement an effective risk reduction and risk communication strategy. Information from many locations under fish consumption advisories can lead to a better understanding of the risks associated with fish consumption, and the choices people make relative to those risks. Knowing whether people fry their fish or eat them whole is important for understanding the risk from some contaminants, such as PCBs, which are stored in the fat and are retained if the whole fish is eaten, or the fish is fried. Grilling fish, and removing the skin, contributes to reducing the fat (and thus PCBs) in the cooked fish.

A discrepancy between knowledge about fishing advisories and the behavior of the fishing public often exists (Burger, Staine, and Gochfeld 1993; Burger, Sanchez, and Gochfeld 1998; Velicer and Knuth 1994; Fleming et al. 1995; May and Burger 1996; MacDonald and Boyle 1997; Burger 1998; Pflugh et al. 1999; Campbell et al. 2002; Burger and Gochfeld 2006). Anglers may either not know about the fish consumption warnings, not know the correct warnings, or choose not to comply with them. Fish consumption advisories may not be followed because people do not trust the government agencies that issue them, do not believe the warnings, or do not agree with the advisories. Most participants of an exposure investigation conducted for the Tennessee River portion of Watts Bar Reservoir continued to eat the same amounts and kinds of fish or turtles even when they were aware of the consumption advisories (US Department of Health and Human Services 1998). Compliance with fish consumption advisories was determined to be limited in a review of creel survey data collected by the Tennessee Wildlife Resources Agency since 1977 for Watts Bar Reservoir; while the angling effort for some species under advisory has decreased, the harvest rates have not declined as expected (Bevelhimer and Adams 1996). The non-compliance of fish consumption advisories may occur because the risks are trivialized in hazards that are familiar and enjoyed, such as fishing and fish

consumption (Burger 2000, 2002). In addition, people may have no other option if fish is their main source of protein. The failure of risk communicators or state agencies to reach the appropriate target audiences may be the partial cause for the failure of anglers to follow fish consumption advisories or select fish or fish cooking methods that reduce risks (Fitzgerald et al. 1995).

Developing an effective risk communication strategy requires an understanding of how ethnicity, income, and education are related to differences in fishing behavior, fish consumption patterns, and potential risk. There were significant differences in the percent of anglers that had heard warnings as a function of ethnicity and income in the study conducted along the Savannah River (Burger 1998), and for people fishing in the New York-New Jersey Harbor (Burger et al. 1999a). Blacks, anglers of lower income, and those with less education were less likely to know about fish consumption advisories in the Florida Everglades (Fleming et al. 1995). For people fishing on Lake Ontario, New York, differences were found in the knowledge about fish safety, with migrant workers being less aware of warnings than others (Velicer and Knuth 1994). These studies indicate that people with lower incomes, and belonging to minority groups often have less knowledge and higher consumption rates of fish from contaminated waters. This study examines fishing within a community with higher overall incomes than have many of the previous studies.

In this paper, we examine fishing and fish consumption patterns of anglers on the Clinch River arm of Watts Bar Reservoir adjacent to the USDOE's Oak Ridge Reservation (ORR) and on Poplar Creek within ORR boundaries (both East Tennessee). Differences in fishing and fish consumption patterns that were related to ethnicity, income, and education were analyzed to provide a framework for designing a risk communication strategy. We test the hypothesis that there were no differences in fish consumption rates as a function of ethnicity, income, education, and years fished in the region. We also examine whether these rates are similar to those from studies in areas with lower average incomes. The study area was within the city of Oak Ridge, a relatively affluent community.

The Clinch River arm of Watts Bar Reservoir is under a fish consumption advisory due to elevated PCBs in striped bass (*Morone Saxatilis*), which should not be eaten. It is also under a precautionary advisory for catfish (*Ictalurus punctatus*) and sauger (*Sander canadense*) because of high PCB concentrations, which means that children, pregnant women, and nursing mothers should not consume either species, and all others should limit consumption to one meal per month. The advisory for Poplar Creek states that no fish should be consumed, and contact with the water should also be avoided because of high concentrations of mercury, PCBs, and other contaminants resulting from current and historical releases from the ORR.

Methods and study area

Study area

The USDOE's 14,200 ha (35,000 acre) ORR, located along the Clinch River arm of Watts Bar Reservoir (Campbell et al. 2002), contains three main nuclear facilities: the Y-12 Plant, the K-25 Site (now known as the East Tennessee Technology Park), and Oak Ridge National Laboratory (ORNL) (Figure 1). Runoff and effluent discharges from all three USDOE facilities enter the Clinch River arm of Watts Bar

Reservoir from either White Oak Creek or Poplar Creek and its tributaries (Bevelhimer and Adams 1996). Contaminants that have been released from the ORR, which was added to the National Priorities List as a Superfund site in 1989, include a variety of radionuclides, metals, and organic compounds that originated from research, industrial, and waste management activities (Bevelhimer and Adams 1996). The Clinch River arm of Watts Bar Reservoir also receives contaminants from other urban and industrial sources.

Subjects and demographics

Two hundred and two people who were fishing in the study area were interviewed either on shore (86%) or on the water by boat (14%) from 10 March 2001 until 1 November 2001. Previous work in the study area, as well as local knowledge, indicated that very few people fished the area during the winter. Information regarding the risk perceptions of these same anglers is presented in Campbell et al. (2002), and below we provide information on demographics in the region, to show that our male study population was similar to the region generally.

Of the 202 people interviewed, 95% were men, 9% were black, 90.5% were white, and one person stated their ethnicity as Chinese (Campbell et al. 2002). The percentage of blacks interviewed was characteristic of the black population in the local area, which is as follows: 8.2% (City of Oak Ridge), 3.9% (Anderson County), 8.6% (Knox County), 1.1% (Loudon County), and 2.7% (Roane County) (US

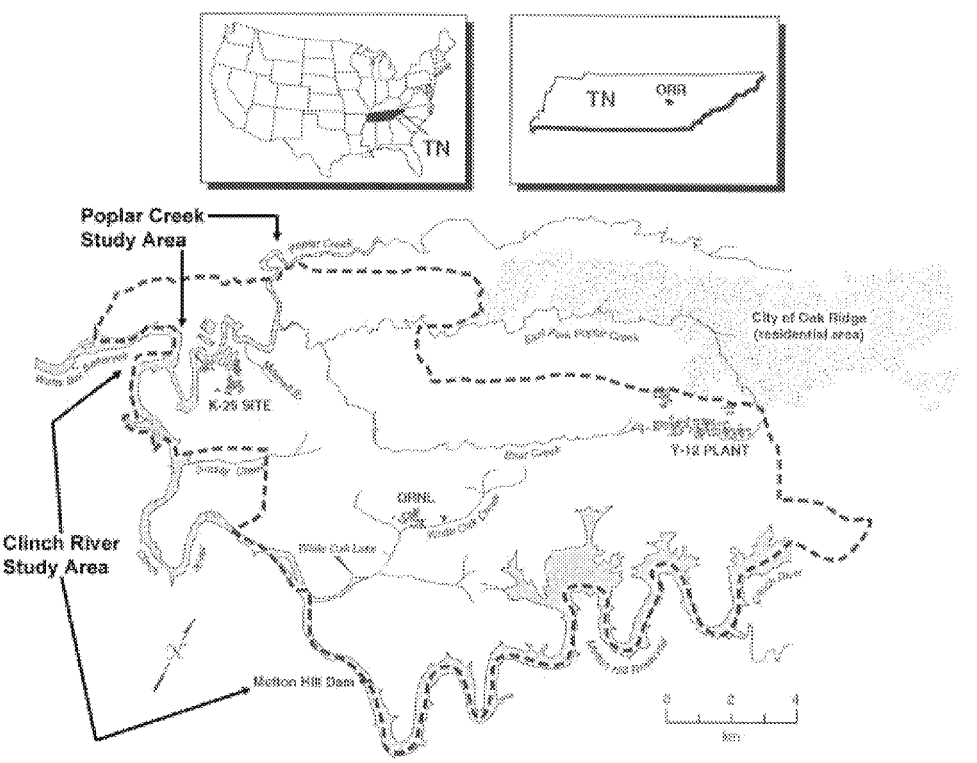

Figure 1. Map of the US Department of Energy's Oak Ridge Reservation in East Tennessee.

Census Bureau 2001a). All ten women interviewed were white, and three people worked or had worked at the ORR. The age of people interviewed averaged 39 years and ranged from 11 to 74 years (Table 1).

The yearly income of anglers interviewed ranged from 0 to $75,000 and averaged almost $31,000 (Table 1). Income estimates for the state of Tennessee are as follows: $36,145 (median household income), $44,120 (median family income), $19,405 (per capita income), $27,205 (median male earnings), and $17,092 (median female earnings) (US Census Bureau 2001b). The yearly income of blacks and whites was not significantly different (Campbell et al. 2002).

The education level of people interviewed ranged from 4th grade to Ph.D. (Table 1). Of anglers interviewed, 18% had less than a high school education, compared to 22.3% for the state of Tennessee (US Census Bureau 2001c). Of the 82% of people interviewed who had finished high school, 23% had at least a bachelors degree. The estimated percent of people in Tennessee who have finished high school and have at least a bachelors degree is 20.9% (US Census Bureau 2001c). There were no significant differences in education level between blacks and whites, as reported in our previous study (Campbell et al. 2002).

Research design

Our overall protocol was to interview anglers in two regions: East Fork Poplar Creek (on the USDOE's ORR) and on the Clinch River. Anglers were interviewed along different sections of the study area depending on the time of year, time of day (whether or not power generation was occurring at Melton Hill Dam), weather, and fishing conditions. When a particular species of fish was being sought after, people

Table 1. Mean (±SE) and range of selected questions asked of anglers along the Clinch River arm of Watts Bar Reservoir.

Question	All anglers interviewed (N=202)		Anglers who catch and eat fish from study area (N=77)	
	Mean	Range	Mean	Range
Number of years fished	31.1±1.09	1–68	33.8±1.87	1–68
Years fished Clinch River/Poplar Creek Study Area	10.9±0.84	0.00274 (1 day)–60	12.4±1.52	0.00274 (1 day)–53
Distance traveled to fish (km)	61.5±5.21	2.4–482	57.5±5.66	2.4–305
How often they eat fish/month	1.28±0.12	0–8	2.06±0.22	0.083–8
Serving size of fish (g)	283±20.9	0–2,268	486±32.7	198–2,268
Fish eaten/month (kg)	0.62±0.08	0–8.96	1.14±0.19	0.04–8.96
Fish eaten/year (kg)	7.40±1.01	0–108	13.68±2.17	0.45–108
Fish eaten/day (kg)	0.02±0.003	0–0.29	0.037±0.006	0.001–0.29
Percent of fish eaten that is fried	95.8±1.54	0–100	78.3±3.50	0–100
Percent of fish eaten that is whole	3.82±1.51	0–100	1.43±0.92	0–50
Percent of fish eaten that is caught by you	76.3±3.21	0–100	88.9±2.68	10–100
Age (yr)	39.4±0.99	11–74	41.8±1.69	14–74
Years of schooling	13.1±0.19	4–22	12.41±0.29	4–18
Income ($)	30,936±1,509	0–175,000	28,804±2,824	0–175,000

often concentrated in a particular portion of the study area, in preference to others. Anglers were interviewed on shore along the 1.6 km reach of the Clinch River immediately below Melton Hill Dam (Melton Hill Dam tailwaters) and along the upper portions of Poplar Creek, where it was accessible from shore along Blair Creek Road. People were consistently found fishing from shore along Melton Hill Dam tailwaters (84% of surveys), although fishing did slack off during July and August. Interviews by boat were not conducted in Melton Hill Dam tailwaters due to the high flow and little warning prior to the release of water from the dam.

Interviews were conducted by boat along the 16 km reach of the Clinch River from below Melton Hill Dam tailwaters to the confluence with Poplar Creek and the lower 6.4 km of Poplar Creek. These areas were surveyed by boat at least once a week, with the exception of July and August when surveys were conducted every two weeks. Despite numerous attempts, people were not found fishing from shore along Upper Poplar Creek once fishing for white bass (*Morone chrysops*) slacked off in early summer, and surveys were discontinued in this area. Approximately 95% of anglers interviewed were found fishing in the Clinch River portion of the study area, while only 10 people were interviewed while fishing in Poplar Creek (Campbell et al. 2002).

Angler interviews began early enough in the year to capture the spring crappie (*Pomoxis* spp.) and white bass fishing seasons, continued throughout the summer when the majority of people were fishing for striped bass, and lasted long enough until the fall crappie fishing season had nearly ceased. The study area included the Clinch River arm of Watts Bar Reservoir from Melton Hill Dam to the confluence with Poplar Creek and Poplar Creek from the confluence with the Clinch River to the intersection with Poplar Creek Road (Figure 1). Because it completely blocks any movement of fish, Melton Hill Dam was chosen as the upstream boundary for the study.

To ensure that anglers interviewed adequately represented the population fishing the study area, people were interviewed on all days and at all times of the day during the study. Since each person was interviewed only once, all anglers encountered, who had not been previously interviewed, were interviewed. Anglers were interviewed on 65 different days, including 48 weekdays and 17 weekend days. Interviews were conducted nearly every week (weather permitting) and from dawn to dusk. People interviewed during the study utilized all types of fishing methods commonly practiced in the study area. The same people, who often asked how the study was progressing, were often seen at the same fishing sites. Approximately 10% of the people approached refused to be interviewed, largely because they were in a hurry (to get more bait shad to keep fishing for striped bass below the dam or to leave) or needed to pay attention to what they were doing (safely navigating their boat in high currents or in the dangerous area just below the dam; Campbell et al. 2002).

People were interviewed using a questionnaire that was almost identical to one used in a similar study conducted along the Savannah River adjacent to the USDOE's SRS in South Carolina (Burger 1998; Burger et al. 1999b). The interview form included questions specific to the study area regarding fishing behavior (how often they fished), fish consumption patterns (how much they ate, and when), fish cooking patterns (fried, broiled or other methods, whole vs fillets), and perceptions about warnings and safety of the fish. Demographic questions were also included and were usually asked at the beginning of the interview. To reduce rejection rates,

more sensitive questions, such as those regarding income, education, and employment, were asked at the end of the interview (Burger et al. 1999b; Burger and Waishwell 2001). Most people had no problem answering sensitive questions at the end of the survey after a long, friendly interview with 'locals' (two people who have lived in the area their entire lives conducted the interviews). Since people were eager to talk about fishing and usually continued to fish during the interview, most interviews took 30 to 45 minutes. For analysis, income was divided into less than $20,000/year and over to provide equivalence to previous studies on fish consumption (see Burger et al. 1999b).

Statistical analysis

Using JMP®'s Fit Y by X Platform, nonparametric analysis of variance (ANOVA) yielding a X^2 statistic was used to determine whether there were ethnic, income, or educational differences among variables associated with fishing behavior, fish consumption, and fish cooking methods, and contingency tables analysis was used to calculate percentages of particular parameters between groups (SAS 2000). A level of $p<0.05$ was accepted as significant.

Results

Fishing behavior and consumption

The fishing behavior, fish consumption patterns, and fish cooking methods of all anglers interviewed, as well as those who caught and ate fish from the study area, are presented in Table 1. Approximately 35% of the people interviewed did not eat fish. Of the 65% who did eat fish, only 38% of them ate fish from the study area. Therefore, since the central topic of this paper is the consumption of fish from the study area, the 38% of anglers interviewed who ate self-caught fish from the study area, which included 71 white anglers (one woman) and six black fishermen, were the main focus of the data analysis.

Anglers who ate fish from the study area included 33% of blacks interviewed and about 42% of whites; three of the anglers (all white men) were found fishing in Poplar Creek when interviewed. They ate an average of 37 g per day, a little more than one kg per month, and almost 14 kg per year of fish from the study area, mainly fried (Table 1). Few people who ate self-caught fish from the study area ate whole fish (most ate fillets), and most ate fish they caught themselves (Table 1). About 23% of anglers who ate fish from the study area ate striped bass, the species under advisory in the Clinch River arm of Watts Bar Reservoir (Table 2). Almost 20% of people who caught and ate fish from the study area ate catfish, while a little over 22% of anglers who ate self-caught fish from the study area ate sauger; both species are under a consumption advisory in the Clinch River arm of Watts Bar Reservoir (Table 2). Crappie was the species most often eaten from the study area that was not under a consumption advisory in the Clinch River arm of Watts Bar Reservoir (Table 2). Approximately 16% of people who ate fish from the study area ate only species under advisory (usually striped bass) in the Clinch River portion of the study area, just about 57% of anglers who ate self-caught fish from the study area ate a combination of species under advisory and not under advisory in the Clinch River arm of Watts Bar Reservoir, and a little over 27% of those who caught and ate fish from the study area ate only species not under advisory (usually crappie).

Table 2. Types of fish eaten by anglers interviewed along the clinch river arm of watts bar reservoir who catch and eat fish from the study area (N=77).

Fish species eaten from the study area	Number of anglers (multiple replies)	Percentage of anglers
Striped bass (*Morone saxatilis*)	18	23.4
Catfish (*Ictalurus* spp.)	15	19.5
Sauger (*Stizostedion canadense*)	17	22.1
Crappie (*Pomoxis* spp.)	49	63.6
White bass, hybrid bass, and striped bass (*Morone* spp.)	26	33.8
Largemouth/smallmouth bass (*Micropterus* spp.)	8	10.4
White bass (*Morone chrysops*)	6	7.8
Walleye (*Stizostedion vitreum*)	2	2.6
Bluegill (*Lepomis macrochirus*)	1	1.3
Yellow perch (*Perca flavescens*)	1	1.3
Rockbass (*Ambloplites rupestris*)	1	1.3
All species	1	1.3

Of those who ate self-caught fish from the study area, 13% had spouses who did not eat fish, 39% had spouses who ate less, more, or the same amount of fish from the study area, and 48% did not have spouses. About 30% of anglers interviewed who caught and ate fish from the study area indicated that their children began eating fish from the study area between 1 and 10 years of age, but mainly between the ages of 2 and 6.

Ethnic differences

With the exception of serving size, there were no significant ethnic differences in fishing behavior, fish consumption, and fish cooking methods of anglers who ate self-caught fish from the study area. The average serving size of fish eaten by whites (501 ± 33.6 g) who caught and ate fish from the study area was significantly larger ($X^2=4.59$, $p=0.032$) than that eaten by blacks (307 ± 116 g). Overall, white anglers had a tendency to eat more fish meals per month than blacks (Figure 2). The distribution of the amount of fish eaten per year for all black and white anglers interviewed is presented in Figure 3.

Of whites who ate self-caught fish from the study area, about 42% had fished the area for less than four years, and 36% of them had fished the area for 5 to 19 years. Five white anglers had fished the area for 20–29 years, five for 30–39 years, four for 40–49 years, and one for over 50 years. Half of the black fishermen who caught and ate fish from the study area had fished the area for 30 to 39 years. One black angler had fished the area for less than four years, one between five and nine years, and one between 10 and 19 years.

Income and educational differences

People who caught and ate fish from the study area who made at least $20,000 per year ate significantly more fish meals per month, ate significantly larger portions of fish, and ate more fish per day, month, and year than those who had an annual income of less than $20,000 (Table 3). These differences are between the

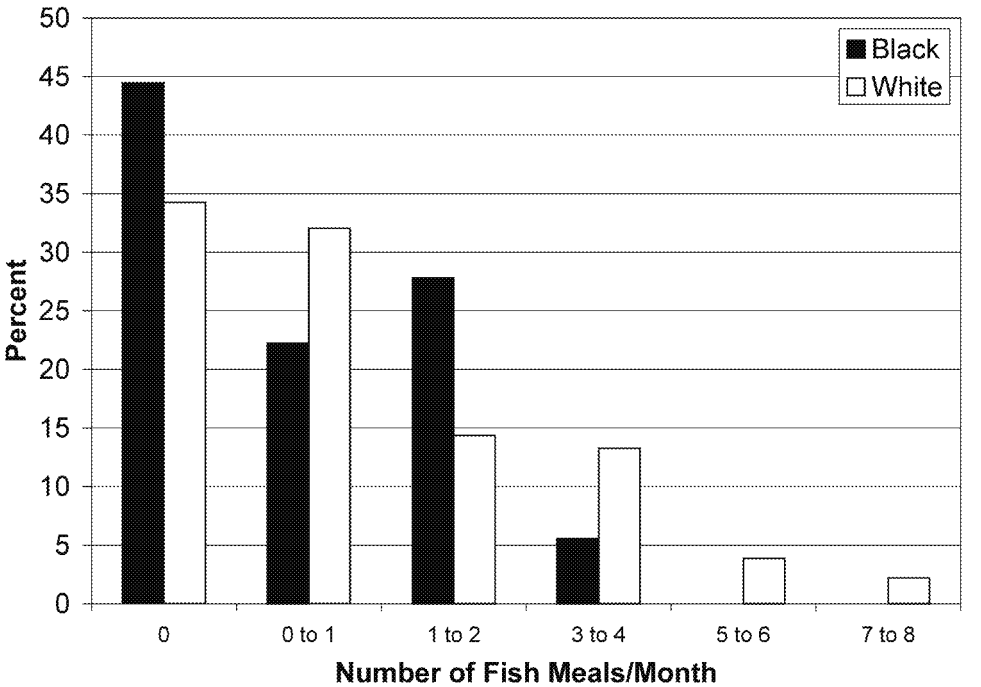

Figure 2. Number of fish meals per month for blacks and whites interviewed in Tennessee.

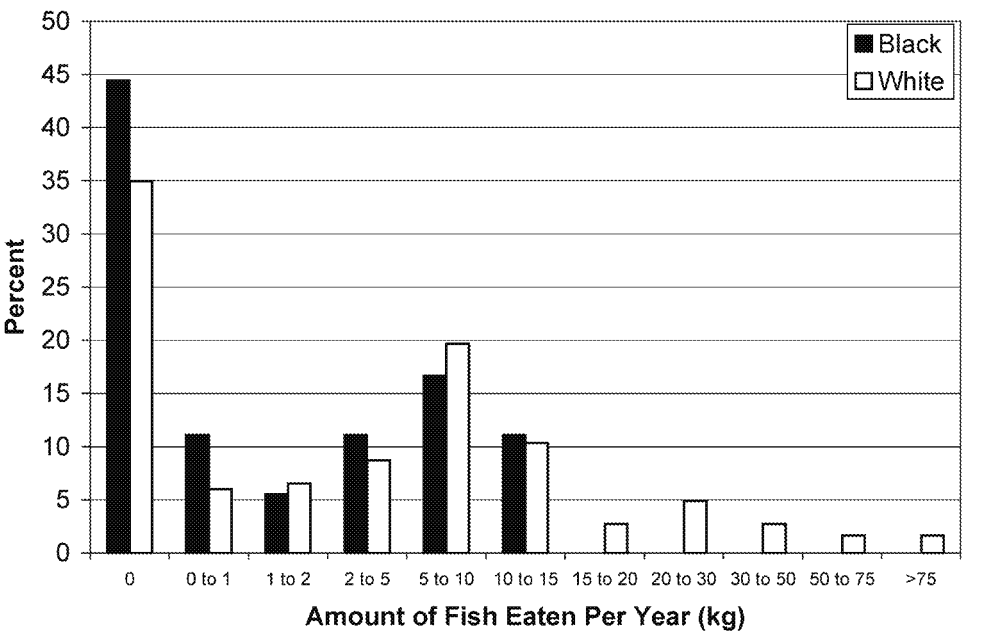

Figure 3. The distribution of the amount (kg) of fish eaten per year for all black and white anglers interviewed on the Clinch River and on Poplar Creek, East Tennessee.

under and over $20,000; when we divided the data by under $20,000, $20,000 to $40,000, and over $40,000, there were no differences between the latter two income categories.

Further, anglers who made less than $20,000 per year ate significantly less fried fish than those who made more money (Table 3). There were no significant educational differences in fishing behavior, fish consumption, or fish cooking methods for people who ate self-caught fish from the study area.

Discussion

Methodological considerations

Sampling biases are unavoidable in any study design that depends on the presence of people at specific locations (Price, Su, and Gray 1994). We interviewed people who were found fishing in the study area during this research and we were, therefore, limited to those people we encountered. Similar to the Savannah River study (Burger et al. 1999b), we conducted our interviews at all times of the day, on all days of the week, and in different portions of the study area to try to reduce bias. To avoid oversampling frequent anglers, we kept track of the names of anglers interviewed, and each person was interviewed only once; names were not entered into the computer database. In addition, to reduce bias due to the selection of anglers interviewed, everyone encountered was approached, and few refused to be interviewed (<10%).

Obtaining accurate information about the consumption of fish from the study area was a top priority since this information is important for estimating risks and developing fish consumption advisories (Reinert et al. 1991). The ability to remember how often fish is eaten and the serving size of a meal is also subject to bias (Burger et al. 1999b). To provide an internal validity check, the amount of fish

Table 3. Income differences (mean ± SE) of anglers interviewed along the Clinch River arm of Watts Bar Reservoir who catch and eat fish from the study area.

Question	Income<$20,000	Income≥$20,000	χ^2 (p)
Number interviewed	22 (29.7%)	52 (70.3%)	
Number of years fished	32.9 ± 3.54	34.2 ± 2.30	NS
Years fished Clinch River/Poplar Creek study area	16.3 ± 2.74	10.4 ± 1.82	NS
Distance traveled to fish (km)	48.9 ± 10.4	62.2 ± 6.98	NS
How often they eat fish/month	1.37 ± 0.41	2.28 ± 0.26	4.32 (0.038)
Serving size of fish (g)	391.7 ± 41.8	497.2 ± 27.2	4.23 (0.039)
Fish eaten/month (kg)	0.52 ± 0.29	1.27 ± 0.19	6.28 (0.012)
Fish eaten/year (kg)	6.29 ± 3.55	15.24 ± 2.31	6.28 (0.012)
Fish eaten/day (kg)	0.017 ± 0.0097	0.042 ± 0.0063	6.28 (0.012)
Percent of fish eaten that is fried	66.7 ± 6.49	81.9 ± 4.22	4.36 (0.037)
Percent of fish eaten that is whole	0	1.15 ± 0.82	NS
Percent of fish eaten that is caught by you	89.1 ± 5.14	88.4 ± 3.34	NS
Age (yr)	42.1 ± 3.19	41.2 ± 2.07	NS
Years of schooling	11.0 ± 0.51	13.0 ± 0.33	5.59 (0.018)

consumed from the study area was asked in three different places on the interview form. The average serving size given for eating fish from the study area on one part of the questionnaire was in complete agreement when compared to the average serving size reported for specific fish species later on during the interview. In addition, all anglers who said they did not eat fish or did not eat fish from the study area later on stated their meal size as zero when asked about eating specific kinds of fish from the study area. To reduce bias and obtain consistent results, anglers were shown a paper mache model of an 8 oz. fish fillet when asked about the amount of fish from the study area they consumed during a meal. Since the ability of people interviewed to distinguish between deep fry and fry in the Savannah River study was shown to be difficult (Burger et al. 1999b), anglers who ate fish from the study area were asked the percent of time they fried their fish. Understanding whether frying is the local method of cooking is important because some contaminants (such as PCBs) reside in the fat, which is retained in frying.

Fish consumption, exposure and risk

Sixty-two percent of the anglers interviewed did not consume fish from the study area and are, therefore, not exposed to the risks associated with eating contaminated fish from the Clinch River arm of Watts Bar Reservoir or Poplar Creek. In an exposure investigation conducted on the Tennessee River portion of Watts Bar Reservoir, about 80% of the 550 people screened ate little or no fish or turtles from the reservoir (US Department of Health and Human Services 1998). In our study, as well as in the above study conducted in the Tennessee River portion of Watts Bar Reservoir, some avid anglers released all or most of the fish they caught.

Long-term risk is a function of the amount of fish consumed, the number of years of exposure, and the amount of contaminants contained in the fish. Unless site-specific information is available, the state of Tennessee uses 6.5 g/day (2.37 kg/year) averaged over a 70 year lifetime as the mean daily consumption rate to calculate risks associated with contaminants when determining fish consumption advisories. Anglers who ate self-caught fish from the study area ate an average of 37 g fish/day (Table 1), and almost 73% of them ate only fish that are under a consumption advisory or a combination of species that are under advisory and those that are not. Even though about 27% of anglers who ate self-caught fish from the study area ate only species that are not under advisory in the Clinch River portion of the study area, they could still be exposed to risks associated with eating contaminated fish. For example, the three anglers who ate self-caught fish from the study area who were interviewed while fishing in Poplar Creek ate only crappie (one ate sauger as well), which is not under advisory in the Clinch River portion of the study area; however, all species of fish are under a consumption advisory in Poplar Creek. Almost 77% of the anglers who caught and ate fish from the study area ate more than 6.5 g fish/day or 2.37 kg fish/year and ate about 89% of fish that they caught themselves, indicating that state risk assessors may be underestimating the risks associated with contaminants in fish species under advisory in the Clinch River arm of Watts Bar Reservoir. Since site-specific consumption information is now available, it should be used to estimate the risks associated with eating fish under a consumption advisory in the study area.

The consumption of fish by humans is usually estimated by multiplying the average number of meals per month by the average serving size to obtain the amount of fish eaten since data on individual fish consumption frequency and serving size are usually not available (Burger et al. 1999b). However, similar to what was found in the Savannah River study, people who ate self-caught fish from the study area also ate larger portions of fish, increasing their yearly consumption (Tables 1 and 2). Thus, more people are at greater risk than would appear by using only averages. Using average values to estimate fish consumption does not provide a complete picture of the consumption patterns of those potentially at highest risk, but systematically biases towards a low estimate. The results of our study, as well as the study conducted along the Savannah River, indicate that individual values should be used to estimate human fish consumption (Burger et al. 1999b).

The average fish consumption rate (37 g/day or 13.7 kg/year) of anglers who ate self-caught fish from the study area was more than two times the mean per capita freshwater/estuarine fish consumption value of 16.6 g/day for the United States (Jacobs et al. 1998). In another investigation, the average consumption of fish by adults in the United States was given as ranging between 13–25 g/day, lower than what was found in this study (US Department of Health and Human Services 1991).

Using only anecdotal information, a consumption rate of 18 g/day, half the average rate found in our study, was used for Clinch River/Poplar Creek recreational anglers in the Oak Ridge Dose Reconstruction Study for PCBs (McLaren/Hart ChemRisk 1999). Similarly, the consumption of more than 15 g/day was considered to be a moderate to large amount of fish consumed from Watts Bar Reservoir in an exposure investigation conducted in 1997 (US Department of Health and Human Services 1998). Even so, the average fish consumption rate of anglers eating fish from this study was lower than the average rate of 48 g/day or 17.6 kg/year of anglers interviewed in the Savannah River study (Burger et al. 1999b).

Most of the people interviewed in this study were men, and all anglers (except one white woman) who ate fish from the study area were men. Anglers were also asked questions regarding the amount of fish from the study area eaten by their spouses and children. About one third of anglers who ate wild-caught fish from the study area indicated that their wives and children also ate fish from the study area; therefore, women and children are clearly eating fish under consumption advisories. The results of our study suggest that women are not avoiding eating fish under advisory, and they are feeding these fish to their children.

In this study, the average time anglers who ate self-caught fish from the study area had fished the area was 12.4 years (Table 1). People who ate fish from the study area had fished the area for less time than those interviewed in two comparable studies. In the Savannah River study, the average time anglers had fished the study area was 24 years (Burger et al. 1999b), while it was 16 years in a study conducted in the Florida Everglades (Fleming et al. 1995). This may relate to the generally more affluent population in the city of Oak Ridge, compared to those living along the Savannah River or in the Everglades of Florida. In many of the regions with USDOE sites, the high-paying jobs are associated with the USDOE, and many are mobile and spend less time in the region (Frisch et al. 1998).

Ethnic, income, and education differences in risk

The study area where this research was conducted is different than other areas of the South where the consumption of wild-caught fish has been investigated (Fleming et al. 1995; Burger 1998; Burger et al. 1999b). For example, in the study conducted on the Savannah River adjacent to the USDOE's SRS, 28% of anglers interviewed were black, while 34% of the population in the local area was black (Burger 1998). In our study, the black population in the local area averaged about 5%, and 9% of anglers we interviewed were black. In addition, unlike the Savannah River study, there were no significant differences in yearly income or education level between blacks and whites in this investigation.

Studies have shown differences in fishing behavior between blacks and whites with respect to attitudes toward fishing (Toth and Brown 1997), but few studies have looked at exposure differences. In Campbell et al. (2002), we presented results showing that significantly fewer blacks knew of the fish consumption advisories for the study area than whites, which was similar to results obtained in many other studies (Velicer and Knuth 1994; Burger 1998; Burger et al. 1999b). However, whites who caught and ate fish from the study area ate significantly larger portions of fish than blacks, and were inclined to eat more fish than blacks, opposite of what was found for the Savannah River and in other studies (Fleming et al. 1995; Toth and Brown 1997; Burger 1998). Our ability to distinguish significant ethnic differences in fishing and fish consumption patterns was limited because of the small sample size of blacks. Ethnic differences may have reached statistical significance with a larger sample of blacks. For example, whites who ate self-caught fish from the study area ate more fish per day, month, and year than blacks, and the difference was close to being statistically significant ($p=0.075$). The results presented in Campbell et al. (2002) indicated that blacks should be the focus of a targeted risk communication program; however, the results presented here demonstrate that all anglers need to be educated and informed.

Opposite of what was found in the Savannah River study in which people with lower incomes ate fish significantly more often than those with higher incomes (Burger 1998), anglers who ate self-caught fish from the study area who made at least $20,000 per year ate significantly more fish meals per month, ate significantly larger portions, and ate significantly more fish per day, month, and year than those with lower incomes (Table 3). This suggests that people fishing the Clinch River arm of Watts Bar Reservoir who ate the most fish are not fishing for subsistence. People with higher incomes may be more aware of the positive benefits of eating fish, but they also need to be informed of the risks associated with eating fish from an area under a consumption advisory. The mean income of the people interviewed at the Savannah River was $21,490 (max was $60,000), compared to $31,000 in this study (maximum of $175,000); this does not seem to us to be a sufficient difference to account for the difference between the two studies. While education contributed most significantly to behavior in the study conducted along the Savannah River, educational differences in fishing behavior and fish consumption were not found in our study.

For risk assessment and risk communication to be useful, site-specific information on fish consumption and demographics is absolutely necessary. If adequate information is not available, targeting the population at risk is not possible. At Oak Ridge, higher income people ate more fish than lower income

people, and the reverse was true at SRS. This indicates the importance of not assuming that fish consumption is highest among lower income people, but indicates the importance of site-specific information. Sensitivity analyses of earlier studies have shown that the fish ingestion rate provides the largest uncertainty associated with dose and risk estimates (US Department of Health and Human Services 1998). Site-specific studies are essential to understand the local dynamics. In the present study, it was not the lower income, less educated anglers who were eating the largest meals of fish the most often, suggesting that there is a real danger in relying on studies from only low income areas to decide on a risk communication strategy. Data from some recent studies are indicating that contaminant levels are sufficiently high in some fish to cause adverse human health effects, and these effects are often found in high income people who can afford to eat expensive fish that are top level predators (Hightower and Moore 2003; Hites et al. 2004)

Acknowledgments

This research was funded by the Consortium for Risk Evaluation with Stakeholder Participation (CRESP) through the Department of Energy (DE-FG26-00NT-40938, DE-FC01-06EW07053) and NIEHS (P30ES005022). We thank all the anglers who took the time to participate in this study, and R.J. Dickey and R. Sexton for help with the interviewing. The analyses and interpretations in this paper are solely the responsibility of the authors and do not necessarily reflect the views of the funding organizations.

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